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EXPRESS MAIL#EL339308467US

FORM PTO-1390 REV. 5-93 US DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE **TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371**	ATTORNEYS DOCKET NUMBER **P99,2243** U.S.APPLICATION NO. (if known, see 37 CFR 1.5) 09/423066

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/DE98/00850	**March 23, 1998**	**April 30, 1997**

TITLE OF INVENTION **METHOD AND ARRANGEMENT FOR DETERMINING AT LEAST ONE DIGITAL VALUE FROM AN ELECTRICAL SIGNAL**

APPLICANT(S) FOR DO/EO/US **STEFAN SCHAEFFLER**

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay.
4. ☐ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.

5. ☒ A copy of International Application (35 U.S.C. 371(c)(2))
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2).

7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. §371(c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.

8. ☒ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)) **(attached at back of English translation of application).**

9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).

10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 C.F.R. 1.97 and 1.98; **(PTO 1449, Prior Art, Search Report).**

12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 C.F.R. 3.28 and 3.31 is included.
    (SEE ATTACHED ENVELOPE)

13. ☒ A FIRST preliminary amendment.
    ☐ A SECOND or SUBSEQUENT preliminary amendment.

14. ☐ A substitute specification.

15. ☐ A change of power of attorney and/or address letter.

16. ☒ Other items or information:
    a. ☒ Submission of Drawings
    b. ☒ Request for Drawing Changes
    ☐ Letter Under Rule Under 37 C.F.R. §1.41(c)
    c. ☒ EXPRESS MAIL #EL339308467US

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U.S.APPLICATION NO. (if known, see 37 C.F.R. 1.5) 09/423066	INTERNATIONAL APPLICATION NO. PCT/DE98/00850	ATTORNEY'S DOCKET NUMBER P99,2243

17. ☒ The following fees are submitted:				CALCULATIONS	PTO USE ONLY
BASIC NATIONAL FEE (37 C.F.R. 1.492(a)(1)-(5): Search Report has been prepared by the EPO or JPO .... $840.00 International preliminary examination fee paid to USPTO (37 C.F.R. 1.482) ... $760.00 No international preliminary examination fee paid to USPTO (37 C.F.R. 1.482) but international search fee paid to USPTO (37 C.F.R. 1.445(a)(2) .... $450.00 Neither international preliminary examination fee (37 C.F.R. 1.482) nor international search fee (37 C.F.R. 1.445(a)(2) paid to USPTO .... $1,250.00 International preliminary examination fee paid to USPTO (37 C.F.R. 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) .... $ 98.00					
ENTER APPROPRIATE BASIC FEE AMOUNT =				$ 840.00	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 C.F.R. 1.492(e)).				$	
Claims	Number Filed	Number Extra	Rate		
Total Claims	19 - 20 =		X $ 22.00	$	
Independent Claims	2 - 3 =		X $ 82.00	$	
Multiple Dependent Claims			$270.00 +	$	
TOTAL OF ABOVE CALCULATIONS =				$ 840.00	
Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 C.F.R. 1.9, 1.27, 1.28)				$	
SUBTOTAL =				$ 840.00	
Processing fee of $130.00 for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$	
TOTAL NATIONAL FEE =				$	
Fee for recording the enclosed assignment (37 C.F.R. 1.21(h). The assignment must be accompanied by an appropriate cover sheet (37 C.F.R. 3.28, 3.31). $40.00 per property +				**SEE ATTACHED ENVELOPE**	
TOTAL FEES ENCLOSED =				$ 840.00	
				Amount to be refunded	$
				charged	$

a. ☒ A check in the amount of $ 840.00 to cover the above fees is enclosed.
b. ☐ Please charge my Deposit Account No. ________ in the amount of $ ______ to cover the above fees. A duplicate copy of this sheet is enclosed.
c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. **08-2290**. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 C.F.R. 1.494 or 1.495 has not been met, a petition to revive (37 C.F.R. 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

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BOX PCT

IN THE UNITED STATES DESIGNATED/ELECTED OFFICE
OF THE UNITED STATES PATENT AND TRADEMARK OFFICE
UNDER THE PATENT COOPERATION TREATY-CHAPTER II

AMENDMENT "A" PRIOR TO ACTION

APPLICANT(S):	Stefan Schaeffler
ATTORNEY DOCKET NO.:	P99,2243
INTERNATIONAL APPLICATION NO.:	PCT/DE98/00850
INTERNATIONAL FILING DATE:	23 March 1998
INVENTION:	"METHOD AND ARRANGEMENT FOR DETERMINING AT LEAST ONE DIGITAL VALUE FROM AN ELECTRICAL SIGNAL"

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Applicants herewith amend the above-referenced PCT application, and request entry of the Amendment prior to examination on the United States National Examination Phase.

IN THE SPECIFICATION:

On substitute page 1, cancel the title and text above line 3, and insert the following above line 3:

--TITLE

METHOD AND ARRANGEMENT FOR DETERMINING AT LEAST ONE DIGITAL SIGNAL FROM AN ELECTRICAL SIGNAL

BACKGROUND OF THE INVENTION

The present invention relates to a method and an arrangement for determining at least one digital signal from an electrical signal.--;

in line 7, cancel "[5]" substitute --Yu-Li You et al., "Blind Equalization by Alternating Minimization for Applications to Mobilecommunications", Globecom '95, IEEE Global

Telecommunications Conference, Singapore, Nov. 14-16 1995, Vol. 1, pp. 88-92,-- therefor;

in line 14, after the semicolon, insert --and--;

in line 15, cancel "A" substitute --a-- therefor;

in line 22, cancel "[2]" substitute --B. Friedrichs, "Kanalcodierung Grundlagen und Anwendungen in modernen Kommunikationssystemen", Springer-Verlag, 1996, pp. 69-125, 193-242,-- therefor;

in line 23, cancel "[3]" substitute --J. Hagenauer et al., "Iterative Decoding of Binary Block and Convolutional Codes", IEEE Trans. on Information Theory, Vol. 42, 1996,-- therefor;

in line 25, cancel "[3]" substitute --J. Hagenauer et al., "Iterative Decoding of Binary Block and Convolutional Codes"-- therefor;

in line 30, cancel "plurality" substitute --number-- therefor;

in line 31, cancel the period.

On page 2, in line 1, after "i=1,...,m" insert a comma;

in line 7, cancel "Lj-values" substitute --L-values-- therefor;

in line 8, after "(3)" insert a period;

in line 11, cancel "words" substitute --word-- therefor;

in line 17, cancel "[1]" substitute --B. Friedrichs, "Kanalcodierung Grundlagen und Anwendungen in modernen Kommunikationssystemen", Springer-Verlag, 1996, pp. 1-30,-- therefor.

On page 3, in line 5, after "function" insert --, which is--;

in line 6, after "channel" insert a comma;

in line 12, after "signal" insert a comma;

in line 17, cancel "words" substitute --word-- therefor;

in line 29, after "as" insert --the--.

On page 4, in line 4, cancel "U_1..., U_m" substitute --U_1, ..., U_m-- therefor;

in line 6, cancel "(⊕)" substitute --(⊕-- therefor;

in line 9, cancel "[3]" substitute --J. Hagenauer et al., "Iterative Decoding of Binary Block and Convolutional Codes-- therefor;

in line 12, cancel "plurality" substitute --number-- therefor;

in line 13, cancel "plurality" substitute --number-- therefor;

in line 20, cancel "c" substitute --C-- therefor.

On page 5, in line 8, after "(9)" insert a period;

in line 13, after "as" insert --a--, and cancel "are" substitute --is-- therefor;

in line 17, after "(11)" cancel the comma;

in line 18, cancel ", respectively".

On page 6, in line 8, cancel "A" substitute --a-- therefor.

On page 7, in line 1, after "(15)" insert a period;

in line 3, cancel "software" substitute --soft-- therefor;

in line 7, after "output)" insert a comma, and after "as" insert --a--.

On page 8, in line 5, after "less" insert --than--;

in line 7, after "for" cancel "the" substitute --a-- therefor, and cancel "equals" substitute --equal-- therefor;

in line 18, cancel "[2]" substitute --B. Friedrichs, "Kanalcodierung Grundlagen und Anwendungen in modernen Kommunikationssystemen", Springer-Verlag, 1996, pp. 69-125, 193-242,-- therefor;

below line 19, insert a centered heading:

--**SUMMARY OF THE INVENTION**--;

in line 20, cancel "The invention is thus based on the problem of specifying" substitute --It is an object of the present invention to provide-- therefor.

On substitute page 9, cancel lines 3-4, substitute the following at line 3:

--This object is achieved in accordance with the invention in a method for determining at least one digital signal value from an electrical signal transmitted via a transmission channel, said electrical signal having signal information and redundancy information for said signal information determined from said signal information. A target function, which has a model of a transmission channel via which the electrical signal was transmitted, is optimized. A dependability degree is approximated. The dependability degree is for forming a digital signal value from the electrical signal based on the optimized target function. A digital signal value dependent on said dependability degree is determined.--;

cancel line 5, substitute the following at line 5:

--A dependability degree--;

cancel line 8, substitute the following at line 8:

--The object of the invention is also achieved in accordance with the invention in an arrangement having a computer unit--;

cancel lines 12-13, substitute the following at line 12:

--In an arrangement for determining at least one digital signal value from an electrical signal transmitted via a transmission channel, the electrical signal having signal information and redundancy information for the signal information determined from the signal information, the arrangement comprises a computer unit having a processor and a memory including a

program operating according to the above described method.

The approximation of the dependability--;

in line 14, cancel "respectively";

in line 21, cancel ", respectively,";

in line 25, after "The" insert --present--;

in line 26, after "calculated" insert a comma;

in line 30, after "signal" insert a comma;

in line 33, cancel ", respectively,".

On substitute page 10, in line 7, after "of" cancel "the" substitute --a-- therefor, and after "probe" insert a comma;

in line 8, cancel "saving" substitute --savings are-- therefor;

in line 9, after "for the" insert --control--;

in line 10, cancel "development or, respectively," substitute --embodiment or when-- therefor, and cancel "the development" substitute --the embodiment-- therefor;

cancel lines 13-14;

in line 15, cancel "a development" substitute --an embodiment-- therefor.

On page 11, in line 4, after "assumed" cancel "the", and cancel "is";

in line 5, cancel "[sic]";

in line 18, cancel "archive" substitute --archived-- therefor, and cancel "[...]" substitute --is contained-- therefor;

cancel lines 22-31;

insert the following at line 22:

--These and other features of the invention(s) will become clearer with reference to the following detailed description of the presently preferred embodiments and accompanied drawings.

DESCRIPTION OF THE DRAWINGS--

Fig. 1 is a flow chart of a method for determining at least one digital signal value from an electrical signal implemented in a computer unit.

Fig. 2 is a block circuit diagram showing the sending, the transmission and the reception of the electrical signals.

Fig. 3 is a block diagram of a radio transmission system.

Fig. 4 is a block diagram of an archiving system for archiving digital data.--;

On page 12, above line 1, insert the following centered heading:

--**DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS**--;

in line 1, cancel "a source 201 proceeding from which a" substitute --a message N proceeding from a source 201 to be-- therefor;

in line 2, cancel "message N is to be";

in line 5, after "message" insert --N--;

in line 10, cancel ", respectively,";

in line 30, after "unit" insert --211--.

On page 13, in line 2, after "receiver unit" insert --211--;

in line 5, after "as" insert --an--;

in line 11, cancel ", respectively,";

in line 20, after "decoding" insert --unit 27--;

in line 26, after "as" insert --a--;

in line 29, cancel "sink" substitute --sync-- therefor.

On page 14, in line 4, cancel "above described" substitute --following-- therefor;

in line 5, after "(16)" cancel the period;

in line 8, cancel "plurality" substitute --number-- therefor;

in line 11, cancel "plurality" substitute --number-- therefor;

in line 13, cancel "gothic".

On page 18, in line 6, cancel "[4]" substitute --S. Schaeffler, "Unconstrained Global Optimization Using Stochastic Integral Equations", Optimization, Vol. 35, 1995, pp. 43-60,-- therefor;

in line 8, after "is" cancel "not";

in line 21, cancel "approximate" substitute --approximated-- therefor;

in line 14, cancel "derives on" substitute --is derived on-- therefor;

in line 16, cancel ", respectively,";

in line 17, cancel "values" substitute --value-- therefor;

in line 19, after "as" insert --a--;

in line 20, cancel ", respectively,".

On page 19, in line 2, cancel ", respectively,";

in line 11, cancel ", respectively,";

in line 16, cancel "[4]" substitute --S. Schaeffler, "Unconstrained Global Optimization Using Stochastic Integral Equations", Optimization, Vol. 35, 1995, pp. 43-60,-- therefor;

in line 24, after "as" insert --an--;

in line 29, cancel "are" substitute --is-- therefor, and cancel "storage" substitute --memory-- therefor.

On page 20, in line 2, after "arrangement" insert --402--;

below line 6, insert the following paragraph:

-- Although modifications and changes may be suggested by those of ordinary skill in the art, it is the intention of the inventors to embody within the patent warranted hereon all changes and modifications as reasonably and properly come within the scope of their contribution to the art.--.

Cancel substitute page 21.

IN THE CLAIMS:

On page 22, in line 1, cancel "**PATENT CLAIMS**" substitute --**I CLAIM AS MY INVENTION:**-- therefor.

Please cancel claims 1-19 and substitute the following claims 20-38 therefor:

20. A method for determining at least one digital signal value from an electrical signal transmitted via a transmission channel, said electrical signal having signal information and redundancy information for said signal information determined from said signal information, the method comprising the steps of:

optimizing a target function having a model of a transmission channel via which said electrical signal was transmitted;

approximating a dependability degree for forming a digital signal value from said electrical signal based on said optimized target function; and

determining said digital signal value dependent on said dependability degree.

21. The method according to claim 20, wherein said step of determining said digital signal value further comprises determining a number of digital signal values from said electrical signal.

22. The method according to claim 20, whereby said model is a non-linear regression model of said transmission channel.

23. The method according to claim 22, wherein said target function is formed according to a rule:

$$f = \sum_{i=1}^{k}\left(\beta_i - \frac{4E_b k}{N_0 n} y_i\right)^2 + \sum_{i=k+1}^{n}\left(\ln\left(\frac{1 + \prod_{j \in J_i} \frac{\exp(\beta_j) - 1}{\exp(\beta_j) + 1}}{1 - \prod_{j \in J_i} \frac{\exp(\beta_j) - 1}{\exp(\beta_j) + 1}}\right) - \frac{4E_b k}{N_0 n} y_i\right)^2 .$$

with

$\beta_i = L(U_i|\underline{y}_i)$, and with

$$L(U_i|\underline{y}) = \ln\left(\frac{\sum\limits_{\substack{\underline{v} \in C \\ \nu_i = +1}} \exp\left(-\frac{\frac{(\underline{y} - \underline{v})^T(\underline{y} - \underline{v})}{N_0 n}}{E_b k}\right)}{\sum\limits_{\substack{\underline{v} \in C \\ \nu_i = -1}} \exp\left(-\frac{\frac{(\underline{y} - \underline{v})^T(\underline{y} - \underline{v})}{N_0 n}}{E_b k}\right)}\right)$$

, and wherein

- N_0 indicates a single-sided noise power density of said transmission channel,
- n indicates a number of digital signal values contained in said transmission channel,
- E_b denotes an average signal energy for one of k digital signal values,
- k denotes a number of digital signal values contained in said electrical signal,
- $\underline{y}$ denotes a vector from $\Re^n$ that describes said electrical signal,
- C denotes a set of all transmission channel code words,

- $\underline{C}$ denotes an n-dimensional random quantity for describing said digital signal value,
- $\underline{v}$ denotes a vector from C,
- i denotes an index for unambiguous identification of said digital signal value v_i,
- U_i denotes a random variable of said digital signal value v_i,
- $L(U_i|\underline{v})$ denotes said dependability degree,
- J_i denotes a set of digital values of said redundancy information, and
- j denotes a further index.

24. The method according to claim 20, further comprising the step of:

subjecting said target function to a global minimization.

25. The method according to claim 20, wherein said dependability degree comprises an operational sign information and an amount information; and whereby said signal value is determined only dependent on said operational sign information.

26. The method according to claim 20, wherein said electrical signal is a systematic block code.

27. The method according to claim 20, wherein said electrical signal is a radio signal.

28. The method according to claim 20, wherein said electrical signal is a restored signal of archived digital data.

29. An arrangement for determining at least one digital signal value from an electrical signal transmitted via a transmission channel, said electrical signal having signal information and redundancy information for said signal information determined from said signal information, said arrangement comprising:

a computer unit having a processor and a memory including a program comprising the steps of:

optimizing a target function having a model of a transmission channel via which said electrical signal was transmitted;

approximating a dependability degree for forming a digital signal value from said electrical signal based on said optimized target function; and

determining said digital signal value dependent on said dependability degree.

30. The arrangement according to claim 29, further comprising a receiver unit for receiving said electrical signal and for supplying said electrical signal to said computer unit.

31. The arrangement according to claim 30, further comprising a demodulator unit for demodulation of said electrical signal, said demodulator having an input connected to said receiver unit and an output connected to said computer unit.

32. The arrangement according to claim 30, wherein said receiver unit is an antenna.

33. The arrangement according to claim 29, wherein said computer unit is programmed to determine a number of digital signal values from said electrical signal.

34. The arrangement according to claim 29, wherein said model in said computer unit program is a non-linear regression model of said transmission channel.

35. The arrangement according to claim 34, wherein said target function in said computer unit program operates according to a rule:

$$f = \sum_{i=1}^{k}\left(\beta_i - \frac{4E_b k}{N_0 n} y_i\right)^2 + \sum_{i=k+1}^{n}\left(\ln\left(\frac{1 + \prod_{j \in J_i} \frac{\exp(\beta_j) - 1}{\exp(\beta_j) + 1}}{1 - \prod_{j \in J_i} \frac{\exp(\beta_j) - 1}{\exp(\beta_j) + 1}}\right) - \frac{4E_b k}{N_0 n} y_i\right)^2 .$$

with

$\beta_i = L(U_i|\underline{y}_i)$, and with

$$L(U_i|\underline{y}) = \ln\left(\frac{\sum_{\substack{\underline{v} \in C \\ \nu_i = +1}} \exp\left(-\frac{(\underline{y} - \underline{v})^T(\underline{y} - \underline{v})}{\frac{N_0 n}{E_b k}}\right)}{\sum_{\substack{\underline{v} \in C \\ \nu_i = -1}} \exp\left(-\frac{(\underline{y} - \underline{v})^T(\underline{y} - \underline{v})}{\frac{N_0 n}{E_b k}}\right)}\right)$$

, and wherein

- N_0 indicates a single-sided noise power density of said transmission channel,
- n indicates a number of digital signal values contained in said transmission channel,
- E_b denotes an average signal energy for one of k digital signal values,
- k denotes a number of digital signal values contained in said electrical signal,

- $\underline{y}$ denotes a vector from $\Re^n$ that describes said electrical signal,
- C denotes a set of all transmission channel code words,
- $\underline{C}$ denotes an n-dimensional random quantity for describing said digital signal value,
- $\underline{v}$ denotes a vector from C,
- i denotes an index for unambiguous identification of said digital signal value v_i,
- U_i denotes a random variable of said digital signal value v_i,
- $L(U_i|\underline{y})$ denotes said dependability degree,
- J_i denotes a set of digital values of said redundancy information, and
- j denotes a further index.

36. The arrangement according to claim 29, wherein said program further comprises the step of:

subjecting said target function to a global minimization.

37. The arrangement according to claim 29, wherein said arrangement is allocated to a radio transmission system.

38. The arrangement according to claim 29, wherein said arrangement is allocated to a system for reconstruction of archived digital data.

IN THE ABSTRACT:

On page 28, in line 1, cancel "**ABSTRACT**" substitute the following centered heading therefor:

--**ABSTRACT OF THE DISCLOSURE**--;

cancel lines 2-13;

in line 5, cancel "The" substitute --An-- therefor, and cancel "[and]" substitute --and-- therefor;

in line 11, cancel "(Step 101)";

in line 12, cancel "(Step 102)".

REMARKS:

The present Amendment revises the specification, drawings and claims to conform to United States patent practice, before examination of the present PCT application in the United States National Examination Phase. All of the changes are editorial and no new matter is added thereby. The cancellation of claims 1-19, in favor of new claims 20-38, has been made solely for convenience, since the amount of bracketing and underlining necessary to editorially amend claims 1-19 in order to conform to United States patent practice would have been excessive and burdensome. The cancellation of claims 1-19 is therefore not intended to be a surrender of any of the subject matter of those claims.

Early examination on the merits is respectfully requested.

Respectfully submitted,

Steven H. Noll (Reg. No. 28,982)

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~~PCT/PTO~~ 1 NOV 1999 09/423066

METHOD AND ARRANGEMENT FOR DETERMINING AT LEAST ONE DIGITAL SIGNAL ~~VALUE FROM AN ELECTRICAL~~ SIGNAL

The goal of the information theory established by Claude Shannon in 1948 is to develop efficient codes for encoding transmission and decoding of digital data and to optimally utilize the available information of the encoded data in the decoding insofar as possible.

[5] discloses an identification of a transmission channel for the transmission of digital data.

Two types of decoding are distinguished in the decoding of digital data:

- in what is referred to as hard decision decoding, a received signal infested with noise by the transmission over a channel is decoded into a sequence of digital data, whereby only the digital value of the respectively received signal is classified;
- in what is referred to as soft decision decoding, an A posteriori probability for the value to be classified is additionally determined for each information character to be decoded. Such a posteriori probabilities are also referred to as soft outputs and form a criterion for the dependability of the decoding.

Soft decision decoding shall be considered below.

Fundamentals of what are referred to as block codes are known from [2].

It is known from [3] to implement a soft decision decoding for a binary, linear block code.

The method from [3] for exact calculation of digital signal values from an electrical signal shall be explained below upon employment of what is referred to as log-likelihood algebra.

It is assumed below that the output of a source encoder of a first arrangement is composed of a sequence of digital, preferably binary signal words that are referred to below as code words. The finite plurality of stochastically independent random variables.

$$U_i: \Omega \rightarrow \{\pm 1\}, \quad i = 1,\ldots,m \; m \in N \qquad (1)$$

is considered, these being defined on a likelihood space (Ω, S, P). S references a σ-algebra, i.e. the set of events for which a likelihood is defined. P references a likelihood criterion ($P:S \rightarrow [0, 1]$). Under the assumption that the inequalities

$$0 < P(\{\omega \in \Omega; U_i(\omega) = 01\}) < 1, \quad i = 1,\ldots,m \qquad (2)$$

are met, what are referred to as Lj-values of the random variables U_i are defined by

$$L(U_i) := \ln\left(\frac{P(\{\omega \in \Omega; U_i(\omega) = +1\})}{P(\{\omega \in \Omega; U_i(\omega) = -1\})}\right), \quad i = 1, \ldots, m \qquad (3)$$

Code words $\underline{u}$ have the following structure:

$\underline{u} \in \{\pm 1\}^k$.

It is thereby assumed for each code words $\underline{u}$ that each digital value u_i, i=1...k of the code word $\underline{u}$ assumes a first value (logical "0" or logical "+1") or a second value (logical "1" or logical "-1") with the same likelihood. Since one must count on disturbances in the transmission of messages that can falsify the messages, a further encoding step, channel encoding, is implemented.

As described in [1], redundancy is intentionally added to the incoming code words $\underline{u}$ in the channel encoding in order to be able to correct possible transmission errors and, thus, assure a high transmission dependability. It is assumed below that a channel code word $\underline{c} \in \{\pm 1\}^n$, $n > k$, $n \in N$, is allocated to each code word $\underline{u} \in \{\pm 1\}^k$. The output of the means for channel encoding is thus composed of code words having the form $\underline{c} \in \{\pm 1\}^n$.

The channel code words are transmitted from a transmission means to a reception means via a physical channel, for example a

subscriber line, coaxial cable, mobile radio telephone, directional radio, etc.

Since the physical channel can often not transmit discrete symbols but only time-continuous signals (i.e., specific functions s: $\Re \rightarrow \Re$), a modulator is often provided with which a function suitable for the transmission via the physical channel is allocated to the channel code word $\underline{c}$. An important characteristic quantity of the transmitted electrical signal is the average energy E_b that is employed for the transmission of an information bit of the channel code word $\underline{c}$.

Since a disturbance can occur in the transmission of an electrical signal via a physical channel, an electrical signal $\tilde{s} : \Re \rightarrow \Re$, that is modified compared to the transmitted electrical signal is received.

The disturbance is described with methods of stochastic signal theory. A characteristic quantity of the disturbance is the known single-side noise power density N_0 that is determined by the channel. After a potential demodulation of the received electrical signal $\tilde{s}$, a vector $\underline{y} \in \Re^n$ is present instead of the code words $\underline{c}$. The absolute amount of each component of the vector $\underline{y}$ is thereby interpreted as dependability information for the corresponding operational sign of the component in the framework of the soft decision decoding.

The channel decoding then has the job - upon employment of the received, potentially demodulated electrical signal $\tilde{s}$ that is ultimately available as vector $\underline{y}$ - of reconstructing the code word $\underline{u}$ that was originally present.

It is standard to model the physical channel and the noise properties thereof. A model frequently employed for this purpose is what is referred to as the invariant AWGN channel (additive Gaussian white noise). When a modulator and a demodulator are present the totality of modulator, physical channel and demodulator is referred to below as channel in this model. Given the AWGN channel, it is assumed that the output of the channel encoder, i.e. the channel code word $\underline{c}$ is additively superimposed by an $N\left(\underline{0}, \frac{N_0 n}{2E_b k}, I_n\right)$ - normally distributed random variable,

whereby I_n references the n-dimensional unit matrix. The quotient $\frac{N_0}{E_b}$ is known and is also referred to as signal-to-noise ratio.

By complete induction for m, it can be shown on the basis of the stochastic independence of the random variables $U_1 \ldots, U_m$ that the following is valid for the L-value of the chained random variables $U_1 \oplus \ldots \oplus U_m$ ($\oplus$) references an exclusive-OR operation):

$$U_1 \oplus U_2 \oplus \ldots U_m: \Omega \rightarrow \{\pm 1\},\ \omega \rightarrow U_1(\omega) \oplus U_2(\omega) \oplus \ldots U_m(\omega) \qquad (4)$$

and

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$$L(U_1 \oplus U_2 \oplus \ldots U_m) = \ln\left(\frac{1 + \prod_{i=1}^{m} \frac{\exp(L(U_i)) - 1}{\exp(L(U_i)) + 1}}{1 - \prod_{i=1}^{m} \frac{\exp(L(U_i)) - 1}{\exp(L(U_i)) + 1}}\right) \qquad (5).$$

The following initial situation derives for the method known from [3]: natural number k, n and sets $J_{k+1}, \ldots, J_n \subseteq \{1, \ldots, k\}$, that describe the properties of the channel encoder are established, as is the non-negative, real number $\frac{N_0}{E_b}$. The plurality of digital values of the code word $\underline{u}$ is referenced k. The plurality of digital values of the channel code word $\underline{c} \in \{\pm 1\}^n$, is referenced n, with n > k. The n-k digital values that are attached to the code words $\underline{u}$ in the formation of the channel code word $\underline{c}$, which are also referred to as check bits, are characterized by $J_{k+1}, \ldots, J_n \subseteq \{1, \ldots, k\}$.

Further, a likelihood space (Ω, S, P) and a small-dimensional random variable C

$$\underline{c}\ \Omega \rightarrow \{\pm 1\}^n \qquad (6)$$

having the following properties is established:

- components

$$C_1,\dots,C_k:\Omega \rightarrow \{\pm 1\} \tag{7}$$

of the n-dimensional random variable $\underline{C}$ are stochastically independent and

$$P(\omega \varepsilon \Omega; C_i(\omega) = -1) = P(\omega \varepsilon \Omega; C_i(\omega) = +1) = \frac{1}{2} \tag{8}$$

applies to all i=1,..., k.

- the following applies to each $i \in \{k+1, \dots, n\}$ and to all $\omega \in \Omega$:

$$C_i(\omega) = \bigoplus_{j \varepsilon J_i} C_j(\omega) \tag{9}$$

The digital values that are formed by the channel encoding, i.e. the channel code words $\underline{c}$, are interpreted as realization of the random variables $\underline{C}$.

The output ũ of the channel decoder to be reconstructed, which is referred to below as set of digital signal values, are the corresponding realization of the random variables

$$U: \Omega \rightarrow \{\pm 1\}^k,\ \omega \rightarrow (C_1(\omega),\dots, C_k(\omega))^T \tag{10}.$$

The output

$$\underline{y} \in \Re^n \tag{11}.$$

of the unit for demodulation or, respectively, the vector that describes the electrical signal and for which the decoding ensues is interpreted as realization of the random variables

$$\underline{Y}: \rightarrow \Re^n,\ \omega \rightarrow \underline{C}(\omega) + \underline{Z}(\omega) \tag{12}$$

whereby $\underline{Z}: \Omega \rightarrow \Re^n$ is $N\left(\underline{0}, \frac{N_0 n}{2E_b k}, I_n\right)$ - normally distributed random variable that is stochastically independent of the n-dimensional random variable $\underline{C}$. The code word ũ is reconstructed based on the vector $\underline{y}$ describing the received electrical signal.

In order to reconstruct the individual digital signal values, the distribution of the random variables C is investigated under the condition that the vector $\underline{y}$ describing the electrical signal was received.

The likelihoods induced by this distribution are referred to as A posteriori likelihoods.

The following quantities are considered for each $\epsilon > 0$:

$$L_\varepsilon\left(U_i|\underline{y}\right) := \ln\left(\frac{P\left(\{\omega \in \Omega; U_i(\omega) = +1\}\middle|\{\omega \in \Omega; \underline{Y}(\omega) \in M_{\underline{y},\varepsilon}\}\right)}{P\left(\{\omega \in \Omega; U_i(\omega) = -1\}\middle|\{\omega \in \Omega; \underline{Y}(\omega) \in M_{\underline{y},\varepsilon}\}\right)}\right) = \ln\left(\frac{\sum\limits_{\substack{\underline{v} \in C \\ v_i = +1}} P\left(\{\omega \in \Omega; \underline{C}(\omega) = \underline{v}\}\middle|\{\omega \in \Omega; \underline{Y}(\omega) \in M_{\underline{y},\varepsilon}\}\right)}{\sum\limits_{\substack{\underline{v} \in C \\ v_i = -1}} P\left(\{\omega \in \Omega; \underline{C}(\omega) = \underline{v}\}\middle|\{\omega \in \Omega; \underline{Y}(\omega) \in M_{\underline{y},\varepsilon}\}\right)}\right) \quad (13).$$

for i = 1,...,k, whereby

$$M_{y,\epsilon} := [y_1, y_1 + \epsilon] \times \ldots \times [y_n, y_n + \epsilon] \quad (14)$$

and C references the set of all channel code words $\underline{c}$.

The following derives by employing the theorem of Bayes:

$$L_\varepsilon(U_i|\underline{y}) := \ln\left(\frac{\sum\limits_{\substack{\underline{v}\in C\\ v_i=+1}} P\left(\left\{\omega\in\Omega;\underline{Y}(\omega)\in M_{\underline{y},\varepsilon}\right\}\middle|\left\{\omega\in\Omega;\underline{C}(\omega)=\underline{v}\right\}\right)}{\sum\limits_{\substack{\underline{v}\in C\\ v_i=-1}} P\left(\left\{\omega\in\Omega;\underline{Y}(\omega)\in M_{\underline{y},\varepsilon}\right\}\middle|\left\{\omega\in\Omega;\underline{C}(\omega)=\underline{v}\right\}\right)}\right)$$

$$= \ln\left(\frac{\sum\limits_{\substack{\underline{v}\in C\\ v_i=+1}} \int\limits_{M_{\underline{y},\varepsilon}} \exp\left(-\frac{(\underline{x}-\underline{v})^T(\underline{x}-\underline{v})}{\frac{N_0 n}{E_b k}}\right)dx}{\sum\limits_{\substack{\underline{v}\in C\\ v_i=-1}} \int\limits_{M_{\underline{y},\varepsilon}} \exp\left(-\frac{(\underline{x}-\underline{v})^T(\underline{x}-\underline{v})}{\frac{N_0 n}{E_b k}}\right)dx}\right) \tag{15}$$

When the boundary transition of (14) for $\varepsilon \to 0$ is considered by multiple employment of the rule of De L'Hospital, then the software outputs $L(U_i|\underline{y})$ are obtained for each character according to the following rule:

$$L(U_i|\underline{y}) = \ln\left(\frac{\sum\limits_{\substack{\underline{v}\in C\\ v_i=+1}} \exp\left(-\frac{(\underline{y}-\underline{v})^T(\underline{y}-\underline{v})}{\frac{N_0 n}{E_b k}}\right)}{\sum\limits_{\substack{\underline{v}\in C\\ v_i=-1}} \exp\left(-\frac{(\underline{y}-\underline{v})^T(\underline{y}-\underline{v})}{\frac{N_0 n}{E_b k}}\right)}\right) \tag{16}$$

The soft outputs that, on the one hand, usually contain an operational sign information and a dependability information (absolute amount of the soft output) are referred to below as dependability degree.

In a completely analogous way, the following is obtained for i = k + 1, ..., n:

$$L\left(\bigoplus_{j \in J_i} U_j \middle| \underline{y}\right) = \ln\left(\frac{\sum\limits_{\substack{\underline{v} \in C \\ v_i = +1}} \exp\left(-\dfrac{(\underline{y} - \underline{v})^T (\underline{y} - \underline{v})}{\dfrac{N_0 n}{E_b k}}\right)}{\sum\limits_{\substack{\underline{v} \in C \\ v_i = -1}} \exp\left(-\dfrac{(\underline{y} - \underline{v})^T (\underline{y} - \underline{v})}{\dfrac{N_0 n}{E_b k}}\right)}\right) \quad (17).$$

The decoding in the known method ensues such that, when the dependability degree exhibits a value greater than 0, the i^{th} component u_i of the code word $\tilde{u}$ to be reconstructed is reconstructed with the second value (logical "1" or logical "-1"). For a value of the dependability degree less 0, the first value (logical "0" or logical "+1") is allocated to the digital signal value. One can arbitrarily decide in favor of the first or the second value for the value of the dependability degree equals to 0. The absolute amount of the dependability degree is a criterion for the dependability of the above decision rules. The reconstruction is all the more dependable the higher the absolute amount.

What is disadvantageous about this known method is the outlay for computer-assisted determination of the dependability degree. The determination of the dependability degree generally requires an outlay for additions that is proportional to min $(2^k, 2^{n-k})$. The direct calculation of the dependability degrees and the determination of the digital values dependent on the dependability degrees is thus often not numerically realizable. Approximately 10^{20} additions would be required for what is referred to as the BCH (255, 191) - Code (see [2]) for the calculation of the 191 dependability degrees and digital signal values.

The invention is thus based on the problem of specifying a method and an arrangement for determining at least one digital signal value from an electrical signal that contains signal information and redundancy information for the signal information determined from the signal

information, whereby a simplified determination compared to the known method is possible.

The problem is solved by the method according to patent claim 1 as well as by the arrangement according to patent claim 10.

Given the method according to patent claim 1, a dependability measure for forming the signal value is approximated from the electrical signal and the signal value is determined dependent on the dependability degree.

The arrangement according to patent claim 10 contains a computer unit that is configured such that a dependability degree for forming the signal value is approximated from the electrical signal and such that the signal value is determined dependent on the dependability degree.

Given the method according to patent claim 1 and given the arrangement according to patent claim 10, further, the approximation of the dependability degree respectively ensues such that a target function is optimized, whereby the target function contains a model of a transmission channel over which the electrical signal was transmitted.

Due to the approximation of the dependability degree that had to be exactly determined hitherto and dependent whereon the signal value is determined, a considerable simplification is achieved in the determination of the digital signal value. This leads to a substantially faster implementation of the method by a computer or, respectively, to considerable saving of costs for the realization of the arrangement for determining the digital signal value. A numerical solution of the soft decision decoding thus often becomes possible at all for the first time.

The invention can be clearly seen therein that the dependability degree that was hitherto only exactly calculated is approximated.

Due to the approximation of the dependability degree by the optimization of the target function, an extremely simple and, thus, quickly implemented possibility is recited that even takes the properties of the transmission channel and, thus, the noise properties of the disturbed signal into consideration.

The minimization of the target function that contains the properties of the channel in the form of the model as approximation criterion leads thereto that the efficiency of the method or, respectively, of the arrangement is substantially improved. As a result of this development, a considerable reduction of the

signal-to-noise ratio $\frac{N_0}{E_b}$ is achieved compared to known methods given the same bit error probability in the determination of the digital signal values. The improvement of the signal-to-noise ratio amounts to up to approximately 3 dB dependent on the channel encoding employed, which would correspond to the maximum improvement that could be theoretically achieved.

A saving of 1 dB, for example, can already lead to a cost saving of approximately 70 million U. S. dollars in the construction of the space probe given radio transmission from space probes. Considerable cost saving is thus possible for the center as well when the decoding ensues according to this development or, respectively, the arrangement according to the development is configured such that the approximation ensues by optimizing a target function that contains a model of the transmission channel.

Advantageous developments of the invention derive from the dependent claims.

In a development both of the method as well as of the arrangement, further, it is advantageous that the target function is formed according to the following rule:

$$f = \sum_{i=1}^{k}\left(\beta_i - \frac{4E_b k}{N_0 n} y_i\right)^2 + \sum_{i=k+1}^{n}\left(\ln\left(\frac{1 + \prod_{j\in J_i} \frac{\exp(\beta_j) - 1}{\exp(\beta_j) + 1}}{1 - \prod_{j\in J_i} \frac{\exp(\beta_j) - 1}{\exp(\beta_j) + 1}}\right) - \frac{4E_b k}{N_0 n} y_i\right)^2 .$$

A modified scaling or a slight modification and neglecting of some values in the target function as well as the degree of the counter function

(degree of the target function) is thereby not critical and can be arbitrarily varied.

This target function indicates a model for the transmission channel in which the assumed the model properties of the transmission channel is [sic] taken into consideration, this supplying extremely good results in the determination of the signal values after the optimization given optimization of the target function, for example, a minimization of the error function.

It is also advantageous to subject the target function to a global minimization since the information contained in the electrical signal is optimally utilized in the framework of the optimization due to this procedure and, thus, is also optimally utilized in the determination of the signal value.

It is also advantageous that the electrical signal is a radio signal and, thus, the arrangement is a radio transmission system with an inventive arrangement, since the method enables substantial savings specifically in the area of radio transmission, particularly in the transmission of radio signals with a space probe.

The method can also be advantageously utilized in the archiving and reconstruction of archive, stored digital data that [...] in a storage medium (for example, magnetic tape store, hard disc store, etc.), since an improved signal-to-noise ratio is also of considerable significance in this application.

Exemplary embodiments of the invention are described in the Figures, these being explained in greater detail below.

Fig. 1 a flow chart wherein the method, which is implemented in a computer unit, is shown in terms of its individual method steps;

Fig. 2 a block circuit diagram, whereby the sending, the transmission and the reception of the electrical signal is shown;

Fig. 3 a sketch of a radio transmission system;

Fig. 4 a sketch of an archiving system for archiving digital data.

Fig. 2 symbolically shows a source 201 proceeding from which a message N is to be transmitted to a sync 209.

The message N to be transmitted is supplied to a source coder 202, where it is compressed such that, although no information is lost, redundancy information superfluous for the decoding of the message is eliminated and, thus, the required transmission capacity is reduced.

The output of the source coder 202 is the code word $\underline{u} \in \{\pm 1\}^k$ that is composed of a sequence of digital values. It is thereby assumed for each code word $\underline{u}$ that each value u_i, i = 1,...k of the code words $\underline{u}$ assumes a first value (logical "0" or logical "+1") or, respectively, a second value (logical "1" or logical "-1") with the same probability.

The code word $\underline{u}$ is supplied to a unit for channel encoding 203 wherein a channel encoding of the code word $\underline{u}$ ensues. In the channel encoding, redundancy information is intentionally attached to the code word $\underline{u}$ in order to be able to correct or at least recognize transmission errors that possibly arise during the transmission and, thus, to achieve a high transmission dependability.

It is assumed below that the channel encoding allocates a channel code word $\underline{c} \in \{\pm 1\}^n$ to each code word $\underline{u} \in \{\pm 1\}^k$. The output of the unit for channel encoding 203 is thus composed of the channel code word $\underline{c} \in \{\pm 1\}^n$.

The channel code word $\underline{c} \in \{\pm 1\}^n$ is supplied to a unit for modulation 204 of the channel code word $\underline{c}$. In the modulation, a function s: $\Re \rightarrow \Re$ suitable for the transmission over a physical channel 205 is allocated to the channel code word $\underline{c}$.

The signal to be transmitted thus contains both signal information, i.e. the channel code word $\underline{c}$, as well as redundancy information determined from the signal information, i.e. additionally contains what are referred to as check values. The modulated signal s is transmitted via the physical channel 205 to a receiver unit. A disturbance 210 that falsifies the modulated signal s often occurs during the transmission over the

physical channel 205. A modified, modulated signal $\tilde{s}$ is thus adjacent at the receiver unit, this being supplied to the unit for demodulation 206.

A demodulation of the modified, modulated signal $\tilde{s}$ ensues in the unit for demodulation 206. The output of the demodulation is a vector $\underline{y} \in \Re^n$ referred to below as electrical signal that describes the digital, demodulated, modified signal $\tilde{s}$.

During the course of further considerations, the model of what is referred to as the AWGN channel is employed for modeling the physical channel 205, as was set forth above. For simplification, both the unit for modulation 204 as well as the unit for demodulation 206 of the transmitter 200 or, respectively, of the receiver 211 is also considered in the model of the transmission channel.

The electrical signal $\underline{y}$ is subjected to a channel decoding in a unit for channel decoding 207. Vector components y_i of the electrical signal $\underline{y}$ contain both an operational sign information as well as an amount information.

The amount information is respectively the absolute value of the vector components y_i that is also referred to as dependability information for the corresponding operational sign of the vector components y_i.

The job in the channel decoding is to implement what is referred to as a soft decision decoding. This means that, first, a reconstructed code word

$\underline{\tilde{u}}$ is reconstructed and, further, a dependability information is determined for each component, this describing the decision made for reconstruction of a component $\tilde{u}_i$ of the reconstructed code word $\underline{\tilde{u}}$. A component $\tilde{u}_i$ of the reconstructed code word $\underline{\tilde{u}}$ is referred to below as digital signal value.

The reconstructed code word $\underline{\tilde{u}}$, i.e. at least one digital signal value, is supplied to a unit for source decoding 208 wherein a source decoding ensues. Finally, the decoded signal is supplied to the sink 209.

The channel decoding 207 is described in greater detail in Fig. 1 in the form of a flow chart.

In a first Step 101, a target function f, which contains a non-linear regression model of the transmission channel 204, 205, 206, is optimized.

The non-linear regression model is derived below for illustration.

From the above-described rule (16) for exact determination of the dependability degree,

$$L(U_i|\underline{y}) = \ln\left(\frac{\sum\limits_{\substack{\underline{v}\in C\\ \nu_i=+1}} \exp\left(-\frac{(\underline{y}-\underline{v})^T(\underline{y}-\underline{v})}{\frac{N_0 n}{E_b k}}\right)}{\sum\limits_{\substack{\underline{v}\in C\\ \nu_i=-1}} \exp\left(-\frac{(\underline{y}-\underline{v})^T(\underline{y}-\underline{v})}{\frac{N_0 n}{E_b k}}\right)}\right) \quad (16).$$

wherein

- N_0 indicates a single-sided noise power density,
- n indicates a plurality of digital signal values contained in the signal,
- E_b denotes an average signal energy for one of the k signal values, i.e. of the information bits,
- k denotes a plurality of digital signal values contained in the electrical signal,
- $\underline{y}$ denotes a vector from gothic $\Re^n$ that describes the signal,
- C denotes the set of all channel code words,
- $\underline{C}$ denotes an n-dimensional random quantity for describing the signal value,
- $\underline{v}$ denotes a vector from C,
- i denotes an index for unambiguous identification of the signal value v_i,
- U_i denotes a random variable of the signal value v_i,
- $L(U_i|\underline{y})$ denotes the dependability degree,
- J_i denotes a set of digital values of the redundancy information, and
- j denotes a further index,

the factor in the numerator,

$$\exp\left(-\frac{(y_i - 1)^2}{\frac{N_0 n}{E_b k}}\right) \tag{18}$$

and the factor in the denominator

$$\exp\left(-\frac{(y_i + 1)^2}{\frac{N_0 n}{E_b k}}\right) \tag{19}$$

can be bracketed out.

After the bracketing, the following rule derives for all i = 1,...,k with corresponding factors τ_i that are now no longer dependent on the components y_i of the electrical signal:

$$L(U_i|\underline{y}) = \ln \frac{\exp\left(-\frac{(y_i - 1)^2}{\frac{N_0 n}{E_b k}}\right)}{\exp\left(-\frac{(y_i + 1)^2}{\frac{N_0 n}{E_b k}}\right)} + \tau_i = \frac{4E_b k}{N_0 n} y_i + \tau_i \tag{20}.$$

The following is valid for i = k + 1, ..., n:

$$L\left(\bigoplus_{j \in J_i} U_j \middle| \underline{y}\right) = \frac{4E_b k}{N_0 n} y_i + \tau_i \tag{21}.$$

If the physical channel 205 were not disturbed, then the observation of the respective components y_i of the electrical signal would suffice for i = 1, ..., k in order to determine the distribution of U_i under the condition that the random variable $\underline{Y}$ assumes the value $\underline{y}$. All factors $\tau_i = 0$ would thus be the case. The situation is analogous for i = k + 1, ...,n with the

distribution $\bigoplus_{j \in J_i} U_j$ under the condition that the random variable $\underline{Y}$ assumes the value $\underline{y}$. In this case, too, all factors $t_i = 0$ would apply. The absolute values of the factors $\tau_1, \ldots \tau_n$ are thus a measure for the channel disturbance.

Under the condition that the signal $\underline{y}$ was received, the stochastic independence of the variables $U_1, \ldots, U_k$ is lost.

Therefore valid for i = k + 1, ..., n with corresponding error factor ρ_i:

$$L\left(\bigoplus_{j \in J_i} U_j \middle| \underline{y}\right) = \ln\left(\frac{1 + \prod_{j \in J_i} \frac{\exp\left(L\left(U_j|\underline{y}\right)\right) - 1}{\exp\left(L\left(U_j|\underline{y}\right)\right) + 1}}{1 - \prod_{j \in J_i} \frac{\exp\left(L\left(U_j|\underline{y}\right)\right) - 1}{\exp\left(L\left(U_j|\underline{y}\right)\right) + 1}}\right) + \rho_i \qquad (22).$$

It is also obvious for the error factors $\rho_{k+1}, \ldots, \rho_n$ that all $\rho_{k+1}, \ldots, \rho_n$ can be set equal to 0 when the physical channel is not disturbed.

The following rule derives overall:

$$\frac{4E_b k}{N_0 n} \underline{y} = \begin{pmatrix} L\left(U_1|\underline{y}\right) \\ \vdots \\ L\left(U_k|\underline{y}\right) \\ \ln\left(\frac{1 + \prod_{j \in J_{k+1}} \frac{\exp\left(L\left(U_j|\underline{y}\right)\right) - 1}{\exp\left(L\left(U_j|\underline{y}\right)\right) + 1}}{1 - \prod_{j \in J_{k+1}} \frac{\exp\left(L\left(U_j|\underline{y}\right)\right) - 1}{\exp\left(L\left(U_j|\underline{y}\right)\right) + 1}}\right) \\ \vdots \\ \ln\left(\frac{1 + \prod_{j \in J_n} \frac{\exp\left(L\left(U_j|\underline{y}\right)\right) - 1}{\exp\left(L\left(U_j|\underline{y}\right)\right) + 1}}{1 - \prod_{j \in J_n} \frac{\exp\left(L\left(U_j|\underline{y}\right)\right) - 1}{\exp\left(L\left(U_j|\underline{y}\right)\right) + 1}}\right) \end{pmatrix} - \begin{pmatrix} \tau_1 \\ \vdots \\ \tau_k \\ \tau_{k+1} - \rho_{k+1} \\ \vdots \\ \tau_n - \rho_n \end{pmatrix} \qquad (23).$$

When the values

$$\begin{array}{lll} \text{for} & i = 1,\ldots,k & L(U_i|\underline{y}) = \beta_i; \quad -\tau_i = e_i \\ \text{for} & i = k+1,\ldots,n & \rho_i - \tau_i = e_i \end{array} \qquad (24),$$

are replaced, then the following non-linear regression problem derives therefrom:

$$\frac{4E_b k}{N_0 n}\,\underline{y} = \begin{pmatrix} \beta_1 \\ \vdots \\ \beta_k \\ \ln\left(\dfrac{1 + \prod\limits_{j \in J_{k+1}} \dfrac{\exp(\beta_j) - 1}{\exp(\beta_j) + 1}}{1 - \prod\limits_{j \in J_{k+1}} \dfrac{\exp(\beta_j) - 1}{\exp(\beta_j) + 1}} \right) \\ \vdots \\ \ln\left(\dfrac{1 + \prod\limits_{j \in J_n} \dfrac{\exp(\beta_j) - 1}{\exp(\beta_j) + 1}}{1 - \prod\limits_{j \in J_n} \dfrac{\exp(\beta_j) - 1}{\exp(\beta_j) + 1}} \right) \end{pmatrix} + \underline{e} \qquad (25).$$

Since an error vector $\underline{e}$ is equal to the 0 vector when no disturbance of the physical channel is established and due to the stochastic model of the channel disturbance, it is assumed that the error vector $\underline{e}$ is a realization of a random variable $E: \Omega \rightarrow \Re^n$ with anticipation value E(E = 0). The dependability degrees are thus approximated by minimization of the influence of the channel disturbance.

Respectively one dependability measure serves for the reconstruction of a respective digital signal value.

The non-linear regression problem is formulated and solved by a target function f when the target f is optimized, minimized in this case.

The target function f is formed according to the following rule:

$$\min\left\{\underline{e}(\beta)^T \underline{e}(\beta)\right\} = \min\{f\}$$

with

$$f = \sum_{i=1}^{k}\left(\beta_i - \frac{4E_b k}{N_0 n} y_i\right)^2 + \sum_{i=k+1}^{n}\left(\ln\left(\frac{1 + \prod_{j \in J_i} \frac{\exp(\beta_j) - 1}{\exp(\beta_j) + 1}}{1 - \prod_{j \in J_i} \frac{\exp(\beta_j) - 1}{\exp(\beta_j) + 1}}\right) - \frac{4E_b k}{N_0 n} y_i\right)^2 \qquad (26).$$

The solution of the non-linear regression problem ensues by minimization of the target function f.

A method for global minimization that is known from [4] is employed for the minimization of the target function f.

The target function f is not generally not convex and it is therefore advantageous to utilize an algorithm for global minimization for the minimization of the target function, because it is possible in this way to optimally utilize the given information in the sense of information theory.

A respective dependability degree is approximate (Step 102) for the components y_i of the electrical signal $\underline{y}$ upon employment of a neural network whose structure derives on the basis of the determined parameters of the optimized target function f.

In a last step 103, the digital signal value or, respectively, the digital signal values $\tilde{u}_i$ is determined from the electrical signal $\underline{y}$ dependent on the dependability degree. The operational sign information of the respective dependability degree is thereby employed as criterion for the allocation of the first or, respectively, of the second value to the digital signal value $\tilde{u}_i$.

When the dependability degree comprises a value greater than 0, then the second value (logical "1" or logical "-1") is allocated to the digital

signal value $\tilde{u}_i$ and, when the dependability degree exhibits a value smaller then 0, then the first value (logical "0" or, respectively, logical "+1") is allocated to the digital signal value $\tilde{u}_i$.

This is implemented for all digital signal values $\tilde{u}_i$ to be reconstructed whose reconstruction is desired.

The arrangement for channel decoding 207 is configured such that the above-described method is implemented. This can ensue by programming a computer unit or can also ensue with an electrical circuit adapted to the method.

A few alternatives and generalizations of the above-described method or, respectively, of the arrangement are disclosed below:

It is not necessary to implement a global minimization of the target function. The minimization can likewise ensue with a method for local minimization, for example with what is referred to as the BFGS method (Broyden, Fletcher, Goldfarb, Shanno method). Further, the minimization of the target function is not limited to the method described in [4]. Further methods for minimization can likewise be utilized.

It is also not necessary that a quadratic norm is minimized as target function; any arbitrary norm of the vector e (β) can generally be utilized.

Fig. 3 shows a radio transmission system that contains an arrangement having the above-described features. A transmission means 301, preferably a space probe, transmits a radio signal 303 via a physical channel 205, in this case through the air. The radio signal 303 is received via an antenna 302 of the receiver arrangement 305 and is supplied as electrical signal to the arrangement 304 that contains the means for demodulation 206, the means for channel decoding 207 as well as the means for source decoding 208.

Fig. 4 shows a system 403 for the reconstruction of archived digital data. Digital data are archived in a storage 401, for example, a magnetic store (magnetic band store, hard disk store, etc.). In the reconstruction, the above-described method for reconstruction of the at least one digital signal value $\tilde{u}_i$ from the electrical signal which, in this case, describes

digital signals read out from the memory 401 can be implemented upon employment of an arrangement having the means for channel decoding 207.

It is clear that the invention can be seen therein that the dependability degree that was hitherto only exactly calculated is approximated.

The following publications were cited in the course of this document.

[1] B. Friedrichs, Kanalcodierung Grundlagen und Anwendungen in modernen Kommunikationssystemen, Springer Verlag, ISBN 3-540-59353-5, pp.1-30, 1996

[2] B. Friedrichs, Kanalcodierung Grundlagen und Anwendungen in modernen Kommunikationssystemen, Springer Verlag, ISBN 3-540-59353-5, pp. 69-125, pp. 193-242, 1996

[3] J. Hagenauer et al, Iterative Decoding of Binary Block and Convolutional Codes, IEEE Trans. On Information Theory, Vol. 42, 1996

[4] S. Schäffler, Unconstrained Global Optimization Using Stochastic Integral Equations, Optimization, Vol. 35, pp. 43-60, 1995

[5] Yu-Li and M.Kaveh, “Blind Equalisation by Alternating Minimization for Applications to Mobilecommunications [sic]”, Globecom ‘95, IEEE Global Telecommunications Conference, Singapore, Nov. 14-16 1995, Vol. 1, pp. 88-92, XP621461

PATENT CLAIMS

1. Method for determining at least one digital signal value from an electrical signal that contains signal information and redundancy information for the signal information determined from the signal information,

- whereby a dependability degree is approximated from the electrical signal for forming the signal value, whereby the approximation of the dependability degree ensues such that a target function that contains a model of a transmission channel via which the electrical signal was transmitted is optimized; and
- whereby the digital signal value is determined dependent on the respective dependability degree.

2. Method according to claim 1, whereby a plurality of digital signal values are determined from the electrical signal.

3. Method according to claim 1 or 2, whereby the model is a non-linear regression model of the transmission channel.

4. Method according to claim 3, whereby the target function is formed according to the following rule:

$$f = \sum_{i=1}^{k}\left(\beta_i - \frac{4E_b k}{N_0 n} y_i\right)^2 + \sum_{i=k+1}^{n}\left(\ln\left(\frac{1 + \prod_{j\in J_i} \frac{\exp(\beta_j) - 1}{\exp(\beta_j) + 1}}{1 - \prod_{j\in J_i} \frac{\exp(\beta_j) - 1}{\exp(\beta_j) + 1}}\right) - \frac{4E_b k}{N_0 n} y_i\right)^2 .$$

with

$\beta_i = L(U_i|y_i)$, and with

$$L(U_i|\underline{y}) = \ln\left(\frac{\sum\limits_{\substack{\underline{v}\in C\\ v_i=+1}} \exp\left(-\frac{(\underline{y}-\underline{v})^T(\underline{y}-\underline{v})}{\frac{N_0 n}{E_b k}}\right)}{\sum\limits_{\substack{\underline{v}\in C\\ v_i=-1}} \exp\left(-\frac{(\underline{y}-\underline{v})^T(\underline{y}-\underline{v})}{\frac{N_0 n}{E_b k}}\right)}\right)$$

whereby

- N_0 indicates a single-sided noise power density,
- n indicates a plurality of digital signal values contained in the signal,
- E_b denotes an average signal energy for one of the k signal values, i.e. of the information bits,
- k denotes a plurality of digital signal values contained in the electrical signal,
- $\underline{y}$ denotes a vector from gothic $\mathfrak{R}^n$ that describes the signal,
- C denotes the set of all channel code words,
- $\underline{C}$ denotes an n-dimensional random quantity for describing the signal value,
- $\underline{v}$ denotes a vector from C,
- i denotes an index for unambiguous identification of the signal value v_i,
- U_i denotes a random variable of the signal value v_i,
- $L(U_i|\underline{y})$ denotes the dependability degree,
- J_i denotes a set of digital values of the redundancy information, and
- j denotes a further index,

the factor in the numerator.

5. Method according to one of the claims 1 through 4, whereby the target function is subjected to a global minimization.

6. Method according to one of the claims 1 through 5,

- whereby the dependability degree comprises an operational sign information and an amount information; and
- whereby the determination of the signal value ensues only dependent on the operational sign information.

7. Method according to one of the claims 1 through 6, whereby the electrical signal is a systematic block code.

8. Method according to one of the claims 1 through 7, whereby the electrical signal is a radio signal.

9. Method according to one of the claims 1 through 8, whereby the electrical signal is a restored signal of archived digital data.

10. Arrangement for determining at least one digital signal value from an electrical signal that contains signal information and redundancy information for the signal information determined from the signal information;
comprising a computer unit that is configured such that
- a dependability degree is approximated from the electrical signal for forming the signal value, whereby the approximation of the dependability degree ensues such that a target function that contains a model of a transmission channel via which the electrical signal was transmitted is optimized; and
- the digital signal value is determined dependent on the respective dependability degree.

11. Arrangement according to claim 10, comprising a receiver unit for receiving the electrical signal and for supplying the electrical signal to the computer unit.

12. Arrangement according to claim 11, comprising a demodulator unit for the demodulation of the electrical signal that is connected via an input to the receiver unit and via an output to the computer unit.

13. Arrangement according to claim 11 or 12, whereby the receiver unit comprises an antenna.

14. Arrangement according to one of the claims 10-13, whereby the computer unit is configured such that a plurality of digital signal values are determined from the electrical signal.

15. Arrangement according to one of the claims 10 through 14, whereby the computer unit is configured such that the model is a non-linear regression model of the transmission channel.

16. Arrangement according to claim 15, whereby the computer unit is configured such
- that the target function is formed according to the following rule:

$$f = \sum_{i=1}^{k}\left(\beta_i - \frac{4E_b k}{N_0 n} y_i\right)^2 + \sum_{i=k+1}^{n}\left(\ln\left(\frac{1 + \prod_{j \in J_i} \frac{\exp(\beta_j) - 1}{\exp(\beta_j) + 1}}{1 - \prod_{j \in J_i} \frac{\exp(\beta_j) - 1}{\exp(\beta_j) + 1}}\right) - \frac{4E_b k}{N_0 n} y_i\right)^2 .$$

with

$\beta_i = L(U_i|y_i)$, and with

$$L\left(U_i \middle| \underline{y}\right) = \ln\left(\frac{\displaystyle\sum_{\substack{\underline{v} \in C \\ v_i = +1}} \exp\left(- \frac{\left(\underline{y} - \underline{v}\right)^T \left(\underline{y} - \underline{v}\right)}{\frac{N_0 n}{E_b k}} \right)}{\displaystyle\sum_{\substack{\underline{v} \in C \\ v_i = -1}} \exp\left(- \frac{\left(\underline{y} - \underline{v}\right)^T \left(\underline{y} - \underline{v}\right)}{\frac{N_0 n}{E_b k}} \right)} \right)$$

whereby

- N_0 indicates a single-sided noise power density,
- n indicates a plurality of digital signal values contained in the signal,
- E_b denotes an average signal energy for one of the k signal values, i.e. of the information bits,
- k denotes a plurality of digital signal values contained in the electrical signal,
- $\underline{y}$ denotes a vector from gothic $\Re^n$ that describes the signal,
- C denotes the set of all channel code words,
- $\underline{C}$ denotes an n-dimensional random quantity for describing the signal value,
- $\underline{v}$ denotes a vector from C,
- i denotes an index for unambiguous identification of the signal value v_i,
- U_i denotes a random variable of the signal value v_i,
- $L(U_i|\underline{y})$ denotes the dependability degree,
- J_i denotes a set of digital values of the redundancy information, and
- j denotes a further index,

the factor in the numerator.

17. Arrangement according to one of the claims 10 through 16, whereby the computer unit is configured such that the target function is subjected to a global minimization.

18. Arrangement according to one of the claims 10 through 17 that is allocated to a radio transmission system.

19. Arrangement according to one of the claims 10 through 17 that is allocated to a system for the reconstruction of archived digital data.

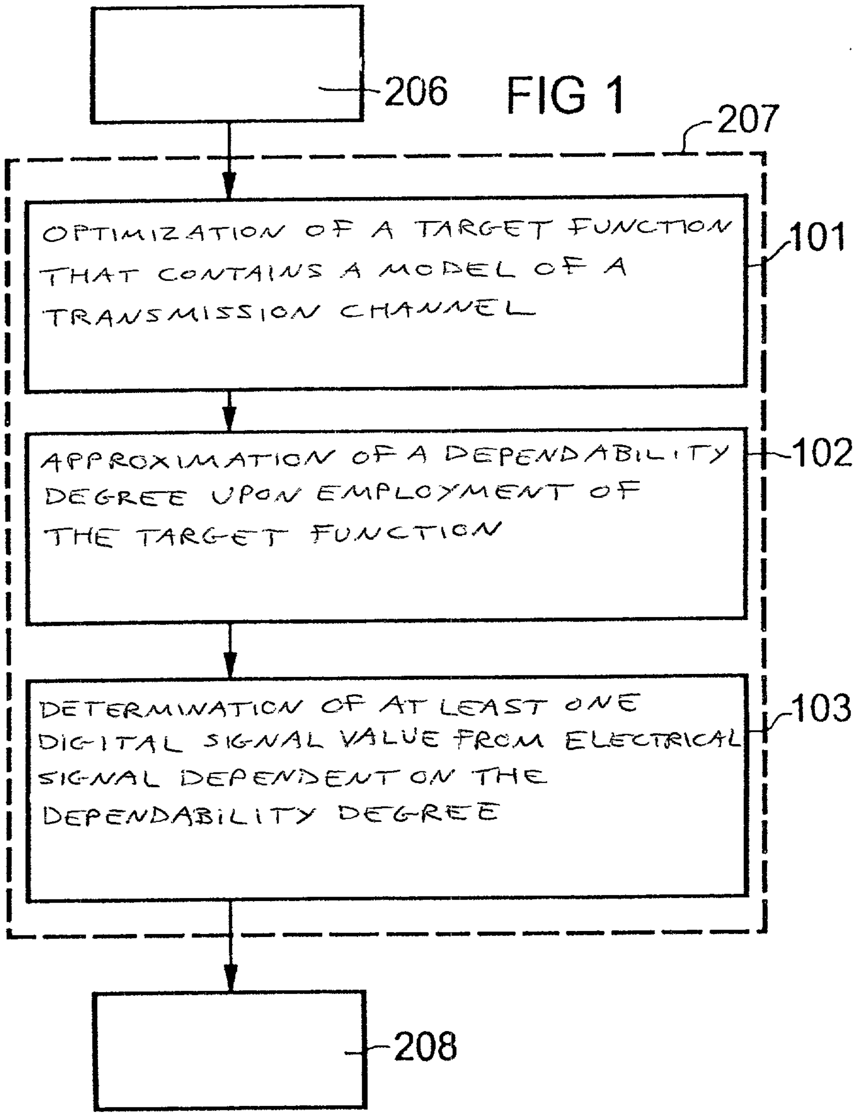
ABSTRACT

Method and Arrangement for Determining at Least One Digital Signal Value from an Electrical Signal

The electrical signal contains signal information [and] redundancy information for the signal information determined from the signal information. A dependability degree is approximated from the electrical signal for forming at least one signal value, and the signal value is determined dependent on the dependability degree. This ensues in that a target function that contains a model of a transmission channel is optimized (Step 101), and the approximation ensues upon employment of the target function (Step 102).

Fig. 1.

FIG 1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207
OPTIMIZATION OF A TARGET FUNCTION THAT CONTAINS A MODEL OF A TRANSMISSION CHANNEL
101
APPROXIMATION OF A DEPENDABILITY DEGREE UPON EMPLOYMENT OF THE TARGET FUNCTION
102
DETERMINATION OF AT LEAST ONE DIGITAL SIGNAL VALUE FROM ELECTRICAL SIGNAL DEPENDENT ON THE DEPENDABILITY DEGREE
103
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FIG 2

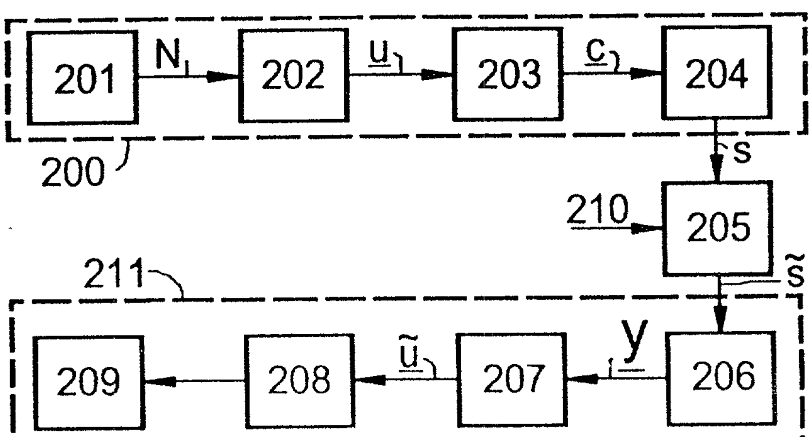
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FIG 3

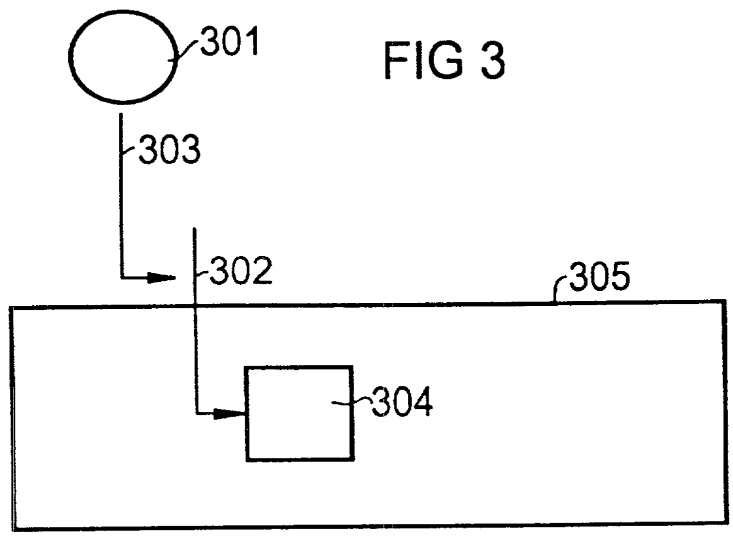
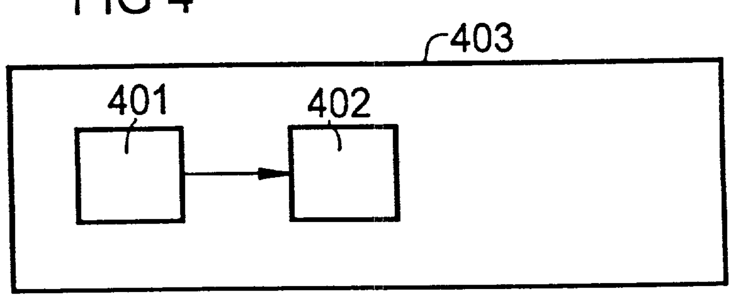


FIG 4



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Verfahren und Anordnung zur Ermittlung mindestens eines digitalen Signalwerts aus einem elektrischen Signal

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

____

deren Beschreibung

(zutreffendes ankreuzen)

☒ hier beigefügt ist.

☐ am __________ als PCT internationale Anmeldung PCT Anmeldungsnummer __________ eingereicht wurde und am __________ abgeändert wurde (falls tatsächlich abgeändert).

the specification of which

(check one)

☐ is attached hereto.

☐ was filed on __________ as PCT international application PCT Application No. __________ and was amended on __________ (if applicable)

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Prior foreign appplications
Priorität beansprucht

Priority Claimed

(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)	Yes Ja	No Nein
197 18 424.3	Germany	30. April 1997	☒	☐
			☐	☐
			☐	☐

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(Application Serial No.) (Anmeldeseriennummer)	(Filing Date) (Anmeldedatum)	(Status) (patentiert, anhängig, aufgegeben)	(Status) (patented, pending, abandoned)
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POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*

And I hereby appoint

Messrs. John D. Simpson (Registration No. 19,842) Lewis T. Steadman (17,074), William C. Stueber (16,453), P. Phillips Connor (19,259), Dennis A. Gross (24,410), Marvin Moody (16,549), Steven H. Noll (28,982), Brett A. Valiquet (27,841), Thomas I. Ross (29,275), Kevin W. Guynn (29,927), Edward A. Lehmann (22,312), James D. Hobart (24,149), Robert M. Barrett (30,142), James Van Santen (16,584), J. Arthur Gross (13,615), Richard J. Schwarz (13,472) and Melvin A. Robinson (31,870), David R. Metzger (32,919), John R. Garrett (27,888) all members of the firm of Hill, Steadman & Simpson, A Professional Corporation.

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Voller Name des zweiten Miterfinders (falls zutreffend):	Full name of second joint inventor, if any:
Unterschrift des Erfinders — Datum	Second Inventor's signature — Date
Wohnsitz	Residence
Staatsangehörigkeit	Citizenship
Postanschrift	Post Office Address

(Bitte entsprechende Informationen und Unterschriften im Falle von dritten und weiteren Miterfindern angeben).

(Supply similar information and signature for third and subsequent joint inventors).